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Evoked Cortical Potentials and Information Processing

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Final Report

Since the inception of this contract, the use of computer generated displays has been emphasized in conjunction with a physiological monitoring system to accomplish the objectives of this research. The computer system has allowed us to present a wide variety of visual stimuli, at very fast rates--from 50 microseconds to one second, in 50 microsecond increments-- at various stimulus intensities. It has enabled us to study sequential blanking, a phenomenon in which up to one-half of ordinarily visible inputs are not perceived because of display input order and rate. We measured visual evoked potentials (VEPs) under conditions of sequential blanking and found that although subjects did not perceive the blanked stimuli, they did respond to them physiologically as indicated by the VEPs. It was also found that sequential blanking could be overcome by increasing the intensity of normally blanked stimuli. On the other hand, if blanking stimuli are made more intense the sequential blanking effect is strength- ened and the VEP to the initial blanked stimulus is delayed in time.

Our research utilized other forms of sensory stimulation as well as other display systems as illustrated by our first study of sensory interaction. It was found that proprioceptive stimulation (induced muscle tension) enhanced the amplitude of cortical response to flashes of light in a number of male subjects. This was found to occur in a series of experimental sessions extending over several weeks. Another experiment on the possible cortical interaction produced by simultaneously presented auditory and visual stimuli indicated that sensory interaction does take place since the cortical evoked potentials differed, both in amplitude or auditory stimuli were presented alone.

If simultaneous presentation of various stimuli affects cortical response, this may provide a possible avenue for affecting human

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performance through alterations in the sensory environment, perhaps enhancing certain types of performance. Some support for this possibility comes from an experiment in which we examined the effects of simultaneous stimulation in two sensory modalities (auditory and visual) upon the auditory evoked potential (AEP) visual evoked potential (VEP) and speed of motor reaction time (RT). It was concluded that bisensory stimulation (simultaneous auditory and visual in this instance) resulted in faster reaction times to a light stimulus than when RTs were obtained under visual stimulation alone. In addition, the AEPs and VEPs underwent significant amplitude and latency changes as a result of bisensory stimulation. For example, the latencies of evoked potentials produced by light and sound combinations were shorter than for those produced by light alone. Amplitude of evoked potentials were greater with bisensory stimulation. Possible anatomical sites of the type of sensory interaction indicated by our results were considered. It was concluded that the ascending reticular formation of the brain was the most likely locus, considering the presently available physiological and anatomical information.

Sensory interaction did not always result in an improvement in performance as indicated by results of another study in which the effects of IMT upon perceptual blanking and evoked potentials was studied. The basic question was whether this form of accessory stimulation (IMT) would overcome the sequential blanking effect, by helping subjects to detect normally blanked stimuli. While the effects of low and moderate IMT was to increase the amplitude of VEPs the perceptual blanking was not overcome by this form of accessory stimulation.

Simple and complex estimates of number and their relation to evoked cortical potentials has been another topic of study. Preliminary findings in this area indicated that with simple light flashes the number of

components in a VEP is related to whether two successive stimuli are below,
at or above a subject's two-flash threshold. This finding indicates that,
for small numbers of simple stimuli at least, the amount of cortical activity
is related to the number of stimuli perceived by an individual, not
necessarily the number actually presented. In a more complex situation,
small (2-6), moderate (12-16) and large (32-36) numbers of dots were
presented on a CRT display very quickly (200 msec) and subjects were asked
to estimate the number presented. The VEP was recorded simultaneously from
left and right occipital areas. It was hypothesized that when these varying
numbers of stimuli were presented rapidly (one-fifth of a second) persons
would engage in a process called "subitizing" with the small number of objects
and "estimating" with larger numbers, and that the different processing tech-
niques would be evidenced as different VEPs. The findings indicated shorter
latency VEPs from the left occipital (visual) hemisphere when individuals
indulged in "estimating" as opposed to "subitizing." There were no latency
differences recorded from the right occipital hemisphere. It was suggested
that subjects may have attempted to count when the objects ranged from 2-6 in
number, and this may have been reflected in longer latency VEPs than when it
was impossible to count (e.g., with 32-36 objects). It was further suggested
that the hemispheres were differentially affected since the left hemisphere
would be dominant for language functions such as counting, in the large
majority of individuals. In a second experiment a limited range of numbers
were tested (10, 16 or 22 objects). This time VEPs with the largest number
of objects showed longer latencies than with the smaller numbers, contrary to
the findings of the first experiment. There was also a trend which persons
with shorter latency VEP components had more accurate numerosity estimates
than those with longer latency responses. Further experimentation is necessary
before any firm conclusion regarding the results of these two numerosity studies

can be made.

The VEP was studied under conditions of four-digit overprinting in another investigation. Overprinting refers to a situation in which randomly generated stimuli are presented sequentially, at a fast rate, in the same location on a CRT display. Performance curves were found to be U-shaped, i.e., identification was good for digits one and four and poor for digits two and three. The VEPs did not reveal any cortical basis for the U-shaped function. However, in a follow-up experiment, in which all conditions were identical except that the third digit in the string of four was more intense, the U-shaped function was disrupted. That is, performance accuracy was greatly improved for the more intense digit and this was reflected in the VEP by the appearance of extra VEP components, related temporally to the presentation of the third digit.

Intensity effects also played a prominent role in the sequential blanking situation as revealed in another experiment in which the intensity ratio between blanking and blanked stimuli was systematically varied. It was found that the greater the ratio of intensities by which the blanking stimuli were more luminous than the blanked ones, the greater the delay in appearance of the VEP to the blanked stimuli. It was concluded that the effects of inhibitory areas in the cortex upon excitatory ones is increased as the intensities of later-appearing, adjacent, visual stimuli are increased. This type of finding has implications for the design of visual displays since objects of greater intensity may affect the perception of less intense adjacent items. Designers must be careful not to let this situation arise.

The effects of three pure tones upon the auditory evoked potential (AEP) was the focus of another experiment. The sound frequencies of 50 Hz, 500 Hz, and 2,500 Hz did not result in different AEPs for the subjects tested. That is, there were no differences in latencies, amplitudes or waveforms of the

evoked cortical potentials as a function of the three pure frequencies used.

The effects of binaural and monaural stimulation upon the AEP recorded from over left and right hemispheres was the topic of another study. Stimuli presented in the right ear resulted in larger amplitude AEPs as recorded from over the left hemisphere, and the opposite occurred when the noise burst stimuli were presented in the right ear. The finding that the amplitude of the AEP was greater in the contralateral as compared to the ipsilateral hemisphere provided further evidence for the predominance of the contralateral pathways of the auditory system. This might mean that stimuli from the right ear have priority over those from the left ear at the site of the left hemisphere and, therefore, have greater access to language processing areas than stimuli arriving from the left ear. Dichotic listening tasks (i.e., where different information is simultaneously presented to right and left ears) have, in fact, shown superiority in the processing of stimuli arriving from the right ear as compared to the left ear.

The relation of the VEP to stimulus shape was the topic of two separate experiments. In the first one a simple, straight line stimulus was presented in either a vertical, horizontal or oblique orientation, in a series of discrete presentations, while the VEP was measured. No alterations of the VEP occurred with respect to latency, amplitude or waveform as a function of the three line orientations. To investigate the possibility that more elaborate shape differences are required to produce VEP differences, a second experiment using squares and circles was performed. Again, there was no evidence for a change in VEP with a change in stimulus configuration.

A question arose as to whether the VEP would reflect marked differences in the perceptual experience of motion, in a situation where the stimulus elements and timing would be identical. The only variation was in display order of stimuli. The computer enabled the production of apparent motion in which

stimuli would appear either to: 1) expand from the center towards the periphery of the display; 2) converge from the periphery at the center of the display; 3) produce a static display spread across the surface of the CRT. Under these three radically different perceptual situations (two involving apparent motion and one not) the VEPs of all subjects were identical. These results indicated that the stimuli were processed objectively by the nervous system, at least as reflected by the occipital areas from over which we recorded. Perhaps some other area of the nervous system produces alterations with the three stimulus conditions, but we obviously did not tap that area.

More recently, we have examined VEPs derived from two locations, O_z (occipital) and C_z (vertex), as a result of apparent and continuous motion. Apparent motion was produced by presenting two vertical lines, in adjacent locations, at a proper inter-stimulus interval. Continuous motion was achieved by presenting a series of vertical lines from left to right on a screen. These two conditions were compared to a situation where the subject perceived two stationary vertical lines. It was found that when continuous motion was perceived the latency of the P2 comonent was significantly delayed when compared to latencies obtained with either the apparent or no motion condition. This was true for VEPs derived from the occipital site. The VEPs obtained from the central recording location did not vary as a function of condition. We believe the VEPs reflect the role of the occipital area as the primary processor of visual stimuli. The results also suggest different brain mechanisms in the processing of continuously moving stimuli versus apparently moving ones.

In a follow-up study, several velocities of apparent motion and continuous motion were compared with respect to the VEPs generated under the various conditions. The two faster velocity continuous motion conditions produced longer latencies than any of the apparent motion conditions.

In addition, the fastest velocity continuous motion condition resulted in the largest amplitude VEPs. The results suggest that a greater amount of cortical processing time (latency results) and greater amounts of cortical activity (amplitude results) occur with continuously moving stimuli as compared to apparently moving ones. This may be due to more complex stimulus processing required in the perception of continuous versus apparent motion. Again, it appears that the VEP results indicate different kinds of cortical processing in apparent and continuous motion.

In a series of studies the effects of multiple sequential stimuli upon both perception and the VEP was examined. In one paradigm two grids were presented, followed by three adjacent grids, thus bounding them on two sides. Finally six grids were presented. The three grids effectively masked the two grids and the six masked both the three and two grids. When this backward masking occurred, it was accompanied by decreased VEP amplitudes to the first two grids. The second experiment replicated the first using different stimuli (letter Bs) and new subjects. Again, backward masking was accompanied by decreases in VEP amplitudes, lending further support to the reliability of the findings. Thus, when backward masking occurred, the magnitude of nervous system response to the masked stimuli was reduced significantly.

In a third experiment it was found that usually effective masking stimuli (grids) did not mask earlier stimuli (letter Bs) when the early ones differed in configuration. The absence of masking was accompanied by a lack of VEP change in amplitude or latency. Hence, the third experiment corroborated the first two since the failure to produce masking also resulted in an absence of change in the VEP. The results were discussed in terms of interactions between exitatory and inhibitory activities produced in the visual cortex by the earlier and subsequently presented stimuli. That is, it was proposed that the early stimuli produced a response in a particular area of

visual cortex. When these stimuli were followed closely enough in time and space, by similar shaped stimuli, the excitatory effect of the early stimuli was inhibited by the response to the later stimuli, resulting in the backward masking observed. The VEP attenuation to a masked stimulus has been produced in a variety of situations in this laboratory including:

1. Target stimulus masked by a visual "noise" pattern.

2. Grid stimulus masked by an identical stimulus which overlapped it directly.

3. Grid stimulus masked by two, three or four others in adjacent locations. In this last case progressively increasing the amount of target-mask contour-interaction led to progressively attenuated VEP amplitudes.

The results obtained lend support to the excitatory-inhibitory model outlined above. That is, the interaction between stimuli arriving at adjacent cortical areas leads to inhibition of response to the initial stimuli by the responses generated by later-presented stimuli.

Investigation of hemipsheric VEP latencies asymmetries as a function of stimulus location has yielded rather consistent results in a variety of studies conducted in this laboratory. In short, a stimulus presented in the left visual field will produce a shorter latency VEP in the right hemisphere than in the left. This is because the primary projection pathways of the stimulus are to the right hemisphere via stimulation of the temporal retina of the right eye and nasal retina of the left eye. That the response occurs at the other hemisphere at all (in this case, the left hemisphere) is due to the visual impulses crossing the cerebral commissures. The opposite effect occurs with stimulation in the right visual field, i.e., shorter latency VEPs in the left hemisphere.

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This final report summarizes research completed at Baruch College of the City University of New York for the period of June 1973 to June 1979. This work was performed in the Psychophysiology Laboratory in the Department of Psychology at Baruch College. A compilation of journal publications and technical reports emanating from this research is also presented.

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